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THE NATIONAL GEOGRAPHIC MAGAZINE

THE NATIONAL GEOGRAPHIC SOCIETY'S ALASKAN EXPEDITION OF 1909

By Ralph S. Tarr, of Cornell University, and Lawrence Martin, of the University of Wisconsin
Leaders of the Expedition

THE research expedition sent out by the National Geographic Society in 1909 devoted the season to a study of glaciers in Yakutat Bay and eastern Prince William Sound, Alaska. Beside the leaders of the expedition, the party consisted of six men. The topographer, Mr W. B. Lewis, of the U. S. Geological Survey, was furloughed by the Survey in order that he might be employed by the expedition. The other members of the party were a photographer, Mr Oscar von Engeln, of Cornell University; a geological assistant, Mr E. F. Bean, of the University of Wisconsin; a boat engineer, one camp hand, and a Japanese cook. The senior author had previously spent two seasons in Yakutat Bay, the junior author one season there and part of another in eastern Prince William Sound.

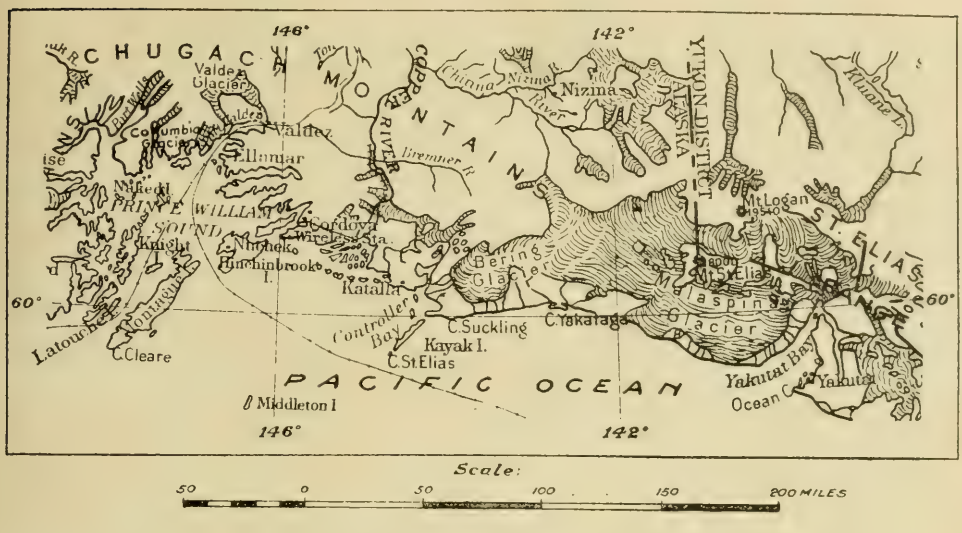
The party sailed from Seattle June 24, going via the Inside Passage and Juneau, and reaching Yakutat five days later. A 28-foot whale-boat with 4-horse-power gasoline engine was used in transporting the party and outfit throughout the summer, though taken on the steamship from Seattle to Yakutat and from Yakutat to Valdez. The first six weeks of the summer were spent in and about Yakutat Bay (June 29 to August 14), the remaining time in eastern Prince William Sound and around the lower Copper River. Two main camps and seven temporary camps were occupied in Yakutat Bay, and three main camps in eastern Prince William Sound. The glacier studies were accomplished by means of travel by water in launch and row-boat, travel by land and glacier on foot, and, in one case, travel by railway automobile over the Copper River and Northwestern Railway.

THE COUNTRY VISITED

The country studied is the mountainous region of the Pacific Coast slope of the Saint Elias and Chugach ranges. These mountains rise to heights of 8,000 to 10,000 feet, with peaks reaching 15,000 to 18,000 feet, and with snow fields covering the whole upland above 2,000 to 3,000 feet, except where the slopes are too steep. The upland is bare, cold, and cheerless; the lowland, quite in contrast, may be covered with spruce and hemlock forest or with luxuriant grass and flowers.

The region has a mild temperature,

MOUNT FAIRWEATHER (15,292 FEET HIGH). PHOTOGRAPHED FROM THE PACIFIC OCEAN BY THE NATIONAL GEOGRAPHIC SOCIETY'S EXPEDITION



THE PACIFIC COAST OF THE GULF OF ALASKA

Showing the location of Yakutat Bay, eastern Prince William Sound, and the lower Copper River region, where the National Geographic Society's Research Expedition spent the summer of 1909 in glacier study.

although in the latitude of Hudson Strait the lofty mountains, rising from the coast in the path of the prevailing westerly winds, cause heavy precipitation—81 to 190 inches annually—a large percentage of which falls on the mountains in the form of snow. Great excess of snow accumulation over melting has resulted in the formation of large valley glaciers, which descend from all the mountains, uniting to form the piedmont Malaspina and Bering glaciers and many intermediate piedmont bulbs.

THE LARGEST GLACIERS OUTSIDE THE POLAR REGIONS

The dimensions of the ice masses present is commensurate with the heavy snowfall and the northern latitude, many of the valley glaciers being of exceptional size. The Hubbard glacier* in Yakutat Bay, for example, has a total known length of 28 miles, only the lower portion being explored. It reaches the sea and discharges icebergs from a tidal cliff nearly five miles long and 250 to 300 feet high. Upon its lower surface three of the largest and best known Swiss glaciers—the Aletsch, Rhone, and Mer de Glace—might be superposed without covering the whole width of the glacier, as shown in the figure (see page 5).

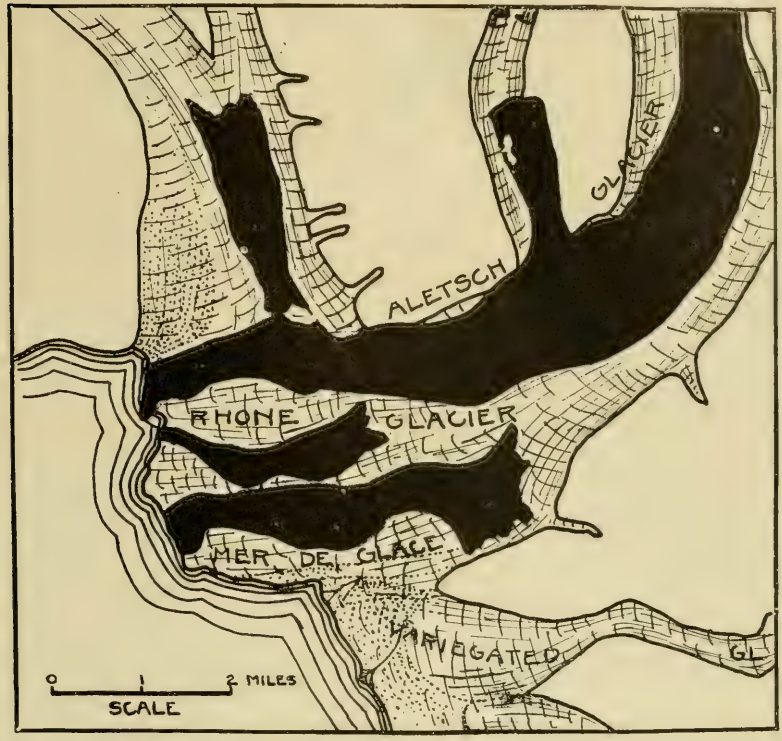
The front of this glacier is so high that a man's figure looks puny against it, and, indeed, a lofty modern office building, such as the Masonic Temple, in Chicago, might stand beside it and the roof would barely overtop the ice cliff, which also extends deep beneath the waters of the fiord. The *Times* building, in New York city, approximately equal in height to the Hubbard or Turner glacier front, is dwarfed by the giant mountains whose 8,000-foot peaks tower in the background.

The whole city of Washington, laid out upon the surface of Columbia glacier, gives a specific conception of the magnitude of these ice masses. One who has walked from the Capitol to the White House, or from the Navy Yard to the

*Named after Gardiner Greene Hubbard, first President of the National Geographic Society, by Prof. Israel C. Russell, who discovered the glacier in 1890 while leading the National Geographic Society Expedition to Alaska of that year.

MAP OF MALASPINA GLACIER, MOUNT SAINT ELIAS, AND YAKUTAT BAY

By Lawrence F. Martin, Department of Geology, University of Wisconsin. This glacier was discovered in 1791 by Alejandro Malaspina, a native of Italy in the service of Spain



THE LOWER PORTION OF THE HUBBARD GLACIER, WITH THREE GLACIERS OF THE SWISS ALPS SUPERIMPOSED UPON IT

All four glaciers are drawn upon the same scale, those from Switzerland being shown from the snowfields to the end of the ice tongue. The contrast of width and length of these glaciers in Switzerland and in Alaska is notable.

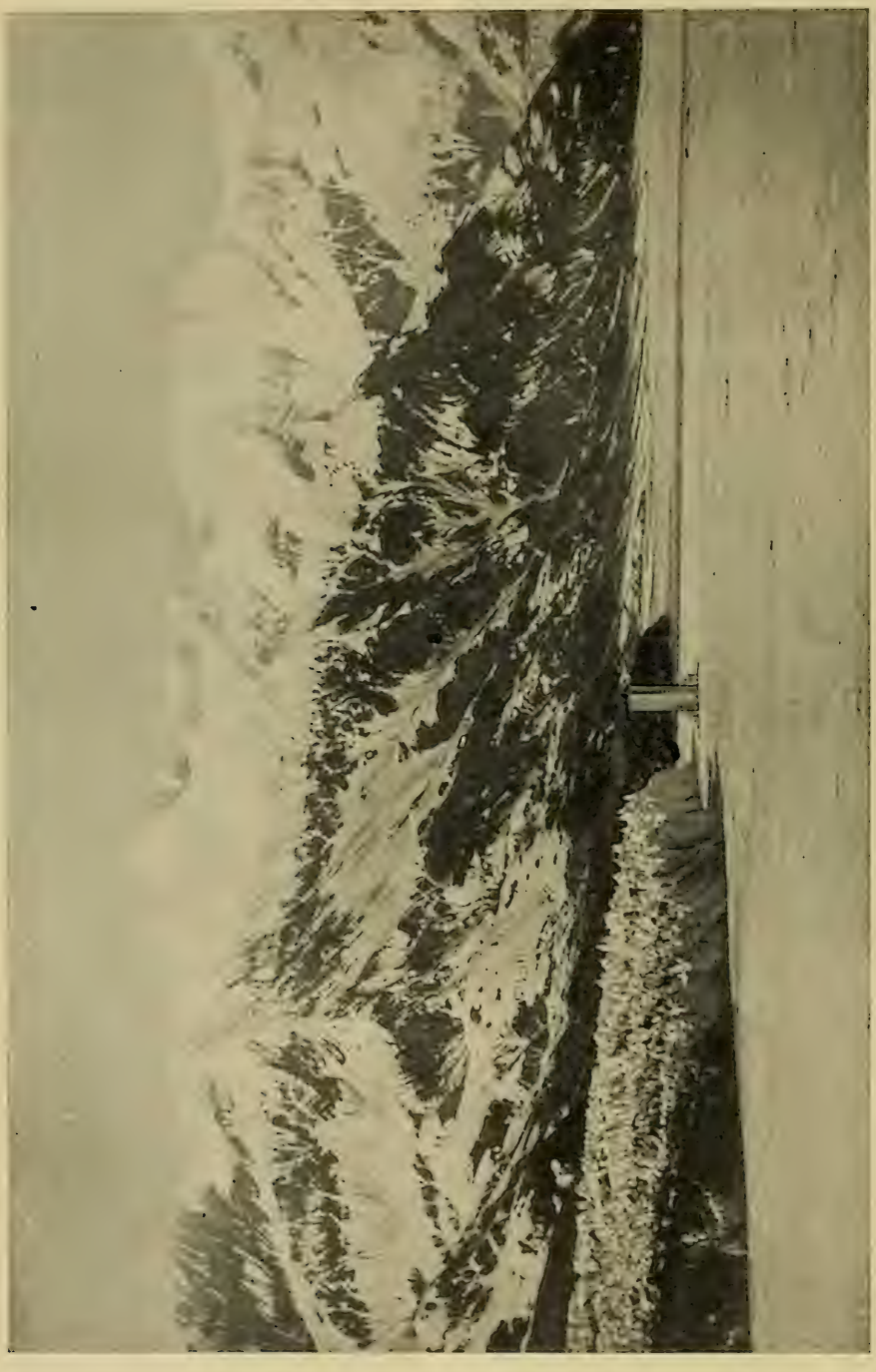
Zoological Park, can appreciate this distance across Columbia glacier (see p. 10).

The Malaspina glacier, however, fed by Agassiz, Seward, Marvine, and other valley glaciers which rival or exceed the Hubbard and Columbia in size, is so large that the whole State of Rhode Island could be laid out upon its 1,500 square miles of surface, or all of eastern Massachusetts. On the accompanying map it may be seen that if Boston were located in the eastern part of the Malaspina glacier the cities of Worcester and Gardner, in central Massachusetts, would be near the west edge (see page 9).

It was with ice masses varying in magnitude from that of Malaspina, Hubbard, and Columbia glaciers to the almost innumerable minor ice tongues that the investigations of the National Geographic Society's Alaskan expedition of 1909 dealt.

INCIDENTS OF A DAY

The day's work in Alaskan glacier study naturally introduces a variety of incidents, with the whole party sometimes united and sometimes divided; one group engaged in observation of the ice tongues, another in making topographic maps, a third in sounding in the fiord, etc. The day may start as early as half past four, and, in one case, began an hour earlier, because the Japanese cook made a mistake. Breakfast is eaten, apparatus and lunches are packed, and the start is made. It is light for twenty to twenty-four hours, so the start and return can be made at convenience.



TURNER GLACIER CLIFF COMPARED IN HEIGHT WITH THE NEW YORK TIMES BUILDING
Mountains in background, 10,000 to 11,000 feet

THE HUBBARD GLACIER CLIFF COMPARED IN HEIGHT WITH THE MASONIC TEMPLE IN CHICAGO

The innumerable branches of a glacial torrent often interpose obstacles to direct travel; the crevasses of a glacier surface make frequent detours necessary. While we were stopping for lunch at a glacier margin one day a series of avalanches built up a deposit of mud and stones 50 feet by 100 and from 5 to 30 feet thick. It contained boulders as much as 6 feet by 4 by 4 and shifted a stream 50 feet laterally into an alder thicket.

A brown bear with a half-grown cub, meeting one on the march and coming up to within 20 feet, lead one to sometimes wish for a gun, and, subsequently, to regret lack of presence of mind in utilizing the camera. The submerging at midnight of a camp on the beach by an exceptionally high tide, so that the water stands 14 inches deep on the tent floor, is not the pleasantest of incidents.

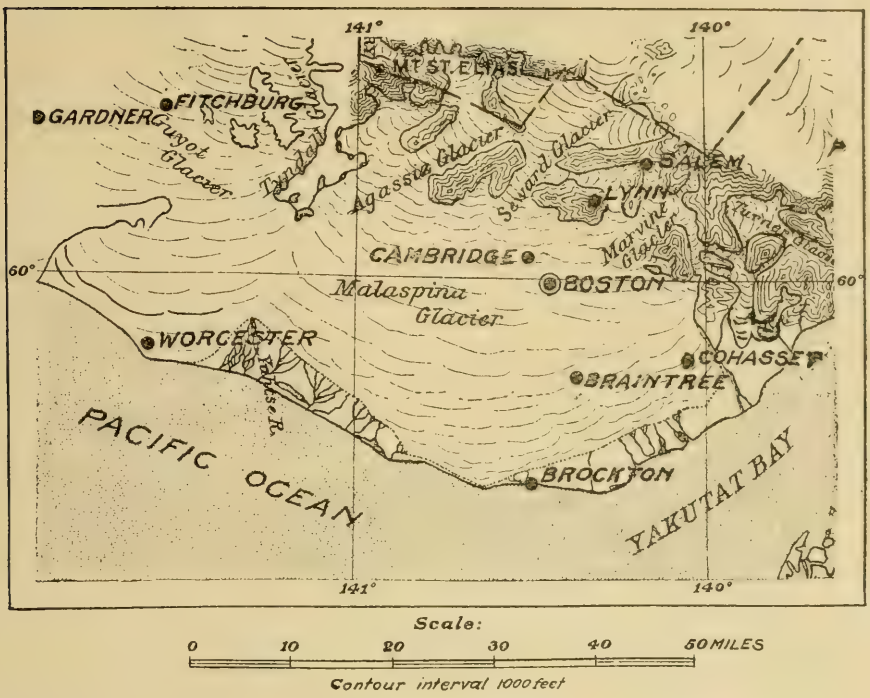
These accidents, however, are easily forgotten exceptions to the general rule of glacier study in Alaska. The series of beautiful panoramas of mountain and plain, fiord and glacier, the excellence and variety of glacial phenomena exhibited—all these lend zest to the work and make the season among the Alaskan glaciers far too short.

THE ENTERPRISE OF VALDEZ

In the regions visited by the National Geographic Society's Expedition the relations of the glaciers to life are striking. When stagnant and moraine-veneered the glaciers are the seat of abundant vegetation, which is destroyed when the ice tongues advance and when they melt and the moraine soil slumps down. As glaciers retreat, vegetation follows. The gravelly stream bottoms are the seat of vegetation which is easily destroyed by the rapidly shifting glacial streams.

The Malaspina and adjacent glaciers are used as highways of travel, the former being utilized by the mountain climbers, Russell, Bryant, and Abruzzi. The Nunatak and Fourth glaciers were crossed by hundreds of prospectors during the gold rushes, the latter being still a highway to the Alsek Valley. Glaciers and glacial streams also erode, transport, and deposit the gold which later concentration has made it profitable to wash on some of the Yakutat Bay beaches.

NUNATAK GLACIER AND ITS ICEBERGS (SEE ALSO PAGES 40 AND 41)



THE MALASPINA GLACIER, THE LARGEST IN THE WORLD OUTSIDE THE POLAR REGIONS

It is larger than Rhode Island or the eastern half of Massachusetts. The distances are shown by the location of the cities of Boston, Worcester, Gardner, Brockton, Cohasset, etc.

In eastern Prince William Sound Valdez glacier is the most famous of the glacier highways, and was traversed in the years of the gold rushes by four or five thousand prospectors.

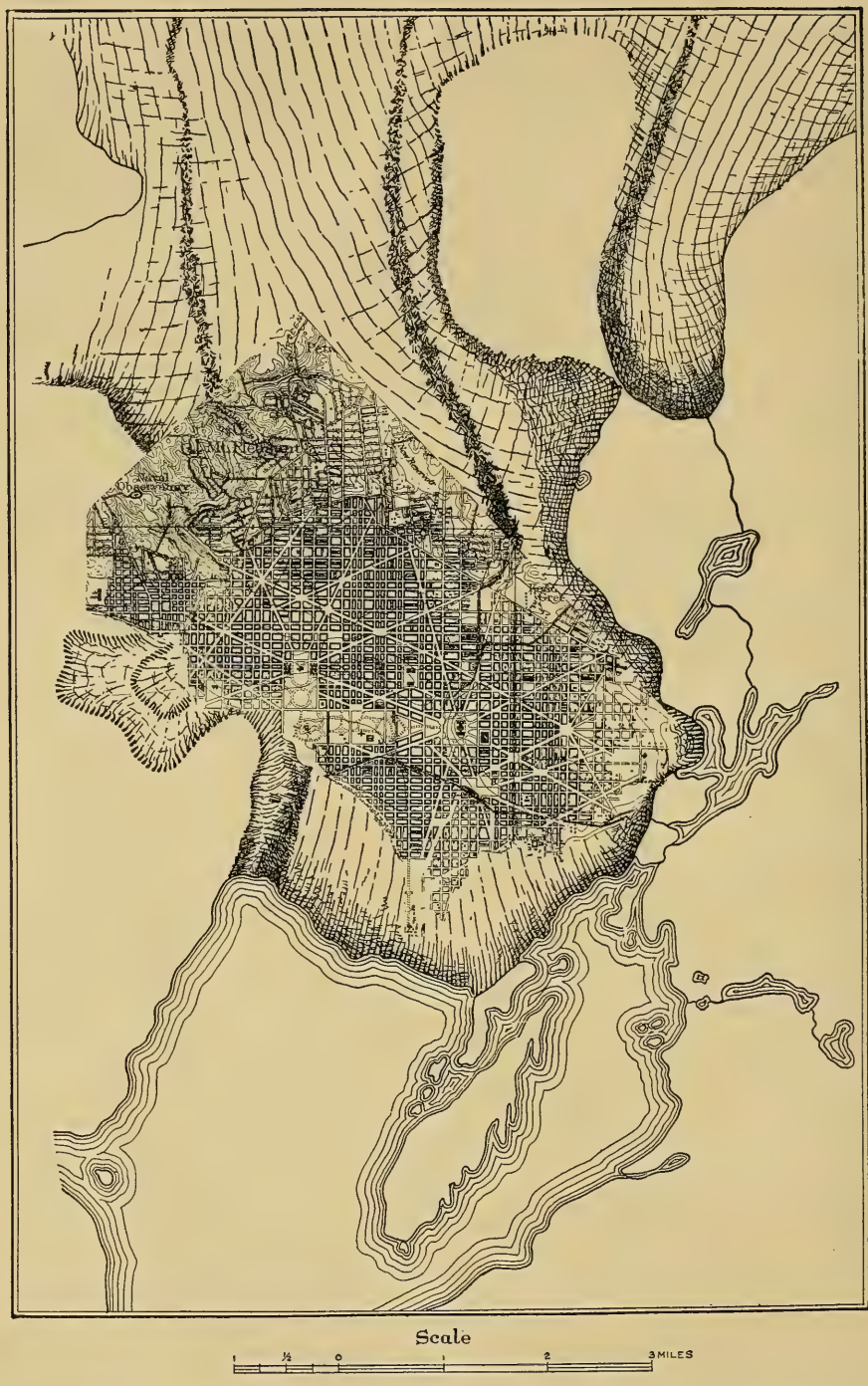
The city of Valdez was located here because this ice-filled pass was possible to cross, and the exact location is determined by the head of ocean navigation on the fiord and a convenient plain built by glacial streams. Not long ago the city was threatened by floods from these same glacial streams. The glacier highway is no longer utilized, but the townsite is an equally convenient terminus to the government telegraph line, trail, and wagon road, several proposed railways, and the winter mail route to the Fairbanks gold camps on the Tanana River.

The enterprise of Valdez citizens has provided an automobile service between the town and the glacier, and on days of steamer visits the automobile makes many trips over the four-mile roadway that connects the glacier and dock. This is probably the only place in the world where automobile service over a glacial outwash plain takes the traveler to the very edge of an ice tongue.

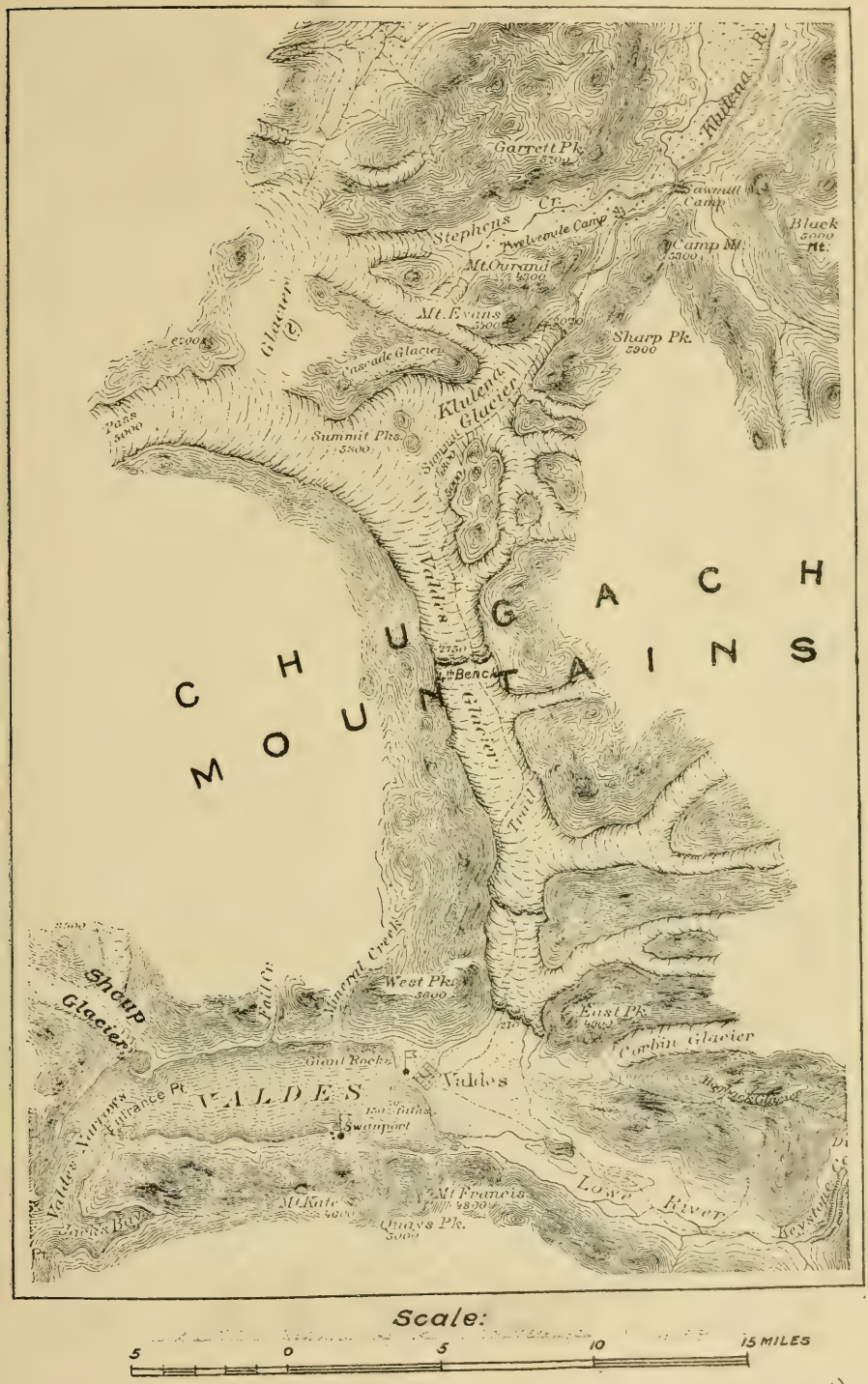
The Shoup glacier, near by on Valdez fiord, is utilized by the United States Army as an ice-house, the soldiers from Fort Liscum, across the bay from Valdez, filling a lighter periodically with small icebergs from this glacier and towing them ten miles to the fort.

FORESTS DESTROYED BY ADVANCING GLACIERS

Around the Columbia glacier, as near the Lucia glacier of Yakutat Bay, the advance of the glacier into mature for-



THE COLUMBIA GLACIER, PRINCE WILLIAM SOUND, WITH THE CITY OF WASHINGTON DRAWN TO THE SAME SCALE FOR PURPOSES OF COMPARISON (SEE PAGES 30-33)



THE VALDEZ GLACIER HIGHWAY (AFTER SCHRADER, MAHLO, AND LOWE)

An ice-filled pass across the Chugach Mountains, crossed by thousands of prospectors. The Shoup glacier, used as an ice-house by the soldiers at Fort Liscum, near Swanport (see page 9)

THE CASCADING GLACIER AND MOUNT DRAPER

That the ice is able to remain on so steep a slope is due to a series of rock terraces, descending westward, which were sculptured by glacial erosion during a higher stage of Nunatak glacier. These terraces form steps upon which the ice rests, giving the appearance of an ice cascade.

ests during the summer of 1909 was resulting in the large-scale destruction of life. Ten years before, Dr G. K. Gilbert and the Harriman Expedition had found that the Columbia glacier was retreating from an advance into the forest, dated tentatively as in 1892. Professor U. S. Grant found that the Columbia glacier retreated 160 feet between 1899 and 1905, and readvanced 112 feet between 1905 and 1908. In the spring of 1909 he observed the continuation of this advance, seen also by the National Geographic Society Expedition in August. Mature trees had grown up to the very edge of Columbia glacier, and a readvance, overturning trees, thrusting splinters of ice up among their very branches, and rolling the peaty soil into great bolsters and terminal moraine ridges, include some of the profoundest effects of glacial conditions upon life (see pp. 32 and 37).

Where the great Copper River breaks through the lofty Chugach Mountains are displayed some of the most striking relationships between glaciers and human life. This water route to interior Alaska has always been blocked by lateral glaciers entering the Copper River Valley and causing ice barriers and rapids in the stream course. Few of the Russians succeeded in getting up the Copper, and difficulties here led to the utilization of the glacier highway at Valdez by most of the prospectors.

The army officer, Abercrombie, ascended to the Miles and Childs glaciers in 1884, and his photographs showing the glaciers and river there are almost identical with present conditions. Lieutenant Allen, in his brilliant explorations of 1885, passed these glaciers, as did Dr C. W. Hayes and Lieutenant Schwatka in 1891.* Hayes made the first detailed map of Miles, Childs, and Baird glaciers.

The map reproduced herewith, modified with a map made in 1900 by Schrader, Gerdine, and Witherspoon, shows the conditions. Miles and Baird glaciers, emerging on opposite sides of the valley, expand in piedmont bulbs. The Copper River writhes between them, forced first against one mountain wall, then the other. Above the glacier dams are lake-like stretches of the river. Childs glacier thus dams the Copper, causing a lake into which Miles glacier discharges icebergs from a cliff three miles long. There are similar slack waters above Miles and Baird glaciers. Opposite the glacier ends the river is constricted into foaming rapids (p. 25).

* National Geographic Magazine, vol. iv, 1892, p. 126.

THE GREATEST SCENIC RAILWAY IN THE WORLD

Under these difficult conditions a railway is being built. Its difficulties include three great bridges across the shifting glacial torrent of Copper River. They include expensive rock cuts, curves, etc., at Abercrombie Rapids, where Miles glacier and the river occupy the whole valley, forcing the railway to the mountain side. They include the laying of five miles of track *on the ice* of Baird glacier, whose advance would destroy the line and whose melting will keep it continually under repairs (see pages 23–25).

The project is daring, unique, but possible. Careful study has determined the necessities. Large capital has enabled wise work. Able engineers, including Messrs E. C. Hawkins, M. J. Heney, and Alfred Williams, who built the White Pass and Yukon Railway, are coping with the problems one by one. Men have never before built railways close to, between, and on great glaciers. But that it can be done is being proved in Alaska. The rich copper deposits north of the Chugach Range, near Mount Wrangell, and perhaps the valuable coal fields of the Controller Bay region, will soon be connected by rail with the growing port of Cordova, on eastern Prince William Sound.

Moreover, this will be the greatest scenic route in the world. Nowhere else can one step from an ocean steamship to a railway car, and ride through foothills, then over a great glacial delta to and between giant ice tongues two and eleven miles respectively in width, around the stagnant, moraine-veneered bulb of the

northern part of Miles glacier, past the beautiful Abercrombie Rapids, and over five miles of the stagnant Baird glacier. Here ice underlies the ties and rails, and a moraine with alders and cottonwoods covers the icy slope on one side, while the other is washed by the Copper River. All this we saw from a railway automobile or on foot, but readers of the NATIONAL GEOGRAPHIC MAGAZINE may see it next year from a train.

MANY GLACIERS SUDDENLY BEGIN A RAPID ADVANCE

In 1890 and 1891, when Professor Russell visited Yakutat Bay, during his explorations of the Mount Saint Elias region, under the auspices of the National Geographic Society and the United States Geological Survey, and in 1899, when Messrs Gilbert, Gannett, and other members of the Harriman Alaska Expedition entered the bay, the glaciers were found to be in a state of general recession. The authors of this article, in 1905, found clear evidence of continued recession of the glaciers of Yakutat Bay, the one notable exception being Galiano glacier.

In 1890 this glacier was covered by a dense growth of alder and cottonwood on its lower, stagnant, moraine-covered end, but in 1905, to our amazement, this forest cover was entirely destroyed. This remarkable change in condition of Galiano glacier puzzled us greatly, and the only hypothesis which we were able to suggest was that the series of vigorous earthquakes that visited the Yakutat Bay region in September, 1899, had in some way caused such an advance in the Galiano glacier as to completely destroy the vegetation which had previously clothed its lower end. The explanation was proposed as only a vague hypothesis forced upon us by the failure of other possible explanations; and we were not only ignorant of the nature of the process and its behavior, but wholly unprepared for the results which the hypothesis necessitated in other neighboring glaciers; for an advancing glacier under earthquake impulse was hitherto an unknown phenomenon of nature.

It was therefore a great surprise to the senior author when he returned to the Yakutat Bay field in the following summer (1906) to find that, although some glaciers had remained unchanged and others had continued their recession, so long in progress, four glaciers had undergone an abrupt and absolute transformation, similar to that of the Galiano glacier prior to 1905. One of these, the Variegated glacier, an alpine glacier of moderate size, which expands in a piedmont bulb beyond the mountain base, was carefully studied in 1905. Its lower end was essentially stagnant and covered with a sheet of ablation moraine arranged in bands of various colors, whence the name of the glacier. Over this moraine we could travel at will in any direction, and up the valley glacier within the mountain walls we made an excursion, in August, finding no other difficulty in traveling over the ice surface than that of an occasional crevasse which broke the otherwise smooth surface, and here and there a mound or ridge of moraine which rose above the clear ice that constituted the larger portion of the glacier within the mountain walls.

Nine months later all this was changed. The smooth, clear ice of the valley portion of the glacier was transformed to a sea of crevasses and seracs, like the broken ice of the ice falls in alpine glaciers; and the crevassing extended out into the moraine-covered piedmont bulb beyond the mountain base. Here not only was the ice so broken that it was impossible to travel on it, but it had thickened perceptibly and advanced noticeably. So great and absolute was the change in so short a time that it seemed almost incredible, and was wholly without precedent.

THE HAENKE GLACIER ADVANCES A MILE IN ONE YEAR

To the west of Variegated glacier lies the great Hubbard glacier, and still farther on the Turner glacier, also large, but

A MEADOW NEAR THE SEA, WHERE THE LUXURIANT VEGETATION CONTRASTS WITH THE BARE, COLD UPLANDS OF THE SAINT ELIAS RANGE

PANORAMA OF HUBBARD GLACIER: HUBBARD MOUNTAIN (12,064 FEET) IN BACKGROUND IN CENTER
This glacier and mountain were named for Gardiner Greene Hubbard, first President of the National Geographic Society. The mountain on the right is Mount Seattle

much smaller than the Hubbard. These two glaciers, ending in the bay in lofty ice cliffs, from which icebergs are constantly being discharged, had not suffered any notable change, but between them are two glaciers, to which no name had as yet been given, one of which, now called the Haenke glacier, had been subjected to changes similar to that of the Variegated glacier, while the other was unchanged. From a nearly stagnant, moraine-covered condition the Haenke glacier had become crevassed to an impassable condition, and its end had moved forward for about a mile. In September, 1905, its visible terminus was on an alluvial fan a quarter of a mile or more from the sea, but in June, 1906, the front was in the sea discharging icebergs and its sea cliff was united with that of Turner glacier.

Still proceeding westward, beyond Turner glacier came the Black glacier, which was unaltered; Galiano glacier, already mentioned, and then Atrevida glacier. In 1905 we were able to ascend the moraine-covered margin of the Atrevida with ease, and we wandered over its ablation moraine at will, while as late as September, 1905, the junior author made a trip completely across the glacier, as Russell had done on his way to Mount Saint Elias in 1890.*

*National Geographic Magazine, vol. iii, 1891, p. 92.

REMARKABLE CHANGES IN THE ALTREVIDA GLACIER

In June, 1906, the Atrevida glacier was marvelously transformed. Its margin was no longer moderately sloping and moraine-covered, but in its place rose a jagged ice cliff, advancing into the forest, and pouring into it a stream of boulders and other morainic debris that was constantly sliding down the newly formed ice cliff. The ice was in motion before our very eyes, and the cracking of the glacier, the tumbling of boulders, and the dislodging of huge ice blocks was heard on every hand. Viewed from a neighboring mountain top it was seen that the entire surface of the Atrevida glacier, from its valley head far out into its expanded, alder-covered piedmont bulb, was a mass of yawning crevasses. Travel over this tumultuous sea of broken ice was utterly impossible, and even the ascent of the margin was possible only by cutting ice steps all the way (see p. 39).

In a period of nine months a stagnant, or nearly stagnant, moraine-covered glacier had advanced, thickened, and become broken into an impassable condition, but neighboring glaciers showed no change from their condition of the previous year. For instance, the Lucia glacier, whose piedmont bulb joins that of the Atrevida on the west, and the Hayden glacier, further west, were unchanged.

West of the Hayden glacier the next large glacier is the Marvine, which descends from the mountains to form the eastern lobe of the great piedmont Malaspina glacier. This had been transformed as the Variegated, Haenke, and Atrevida had been. Where Russell easily crossed it in 1890, near its emergence from the mountain valley, the Marvine was now an impassable sea of seracs, and the eastern portion of the Malaspina, as far as Point Manby, at the western entrance to Yakutat Bay, was so broken that travel over its surface was no longer possible; yet it was over this portion of the Malaspina glacier that Russell traveled in 1890 and the Duke of the Abruzzi and Mr Bryant in 1897. The junior author saw the Malaspina and terminus of the Marvine in September, 1905, when it seemed exactly as in 1890. In 1906 the whole eastern margin of the Malaspina was observed by the senior author as a broken, jagged ice cliff, which was advancing in August, 1906, and destroying the forest that grew in the ablation moraine that had accumulated on this stagnant portion of the glacier.

EXPLANATION OF THE ADVANCE

In seeking an explanation for these phenomena there was no assistance to be gained from previous records of glacial changes, for such abrupt transformation of glaciers had never before been witnessed. Some unusual cause must have been in operation to have transformed stagnant ice into the broken, crevassed condition of rapidly moving glaciers, and to have caused a sudden forward movement and thickening of the lower portions of the glacier. Such an unusual cause at once suggested itself, for in September, 1899, the Yakutat Bay region was the center of a series of earthquake disturbances of great severity, and to the study of the effects of these earthquakes we had in 1905 given much attention, finding clear evidence of an uplift of the coast line (in one place to an elevation of 47 feet), of depression, of several fault lines, and of numerous avalanches.

As a result of a consideration of the phenomena observed in 1906 and of their possible explanation the senior author put forward the following theory as the only one that could adequately account for the facts, and against which there were no fatal objections:

In September, 1899, the severe shaking of the mountains during the earthquakes caused extensive avalanches of snow, ice, and rock from the lofty mountains into the reservoir of the glaciers of the Yakutat Bay region. This added so much to their supply that in time a response must necessarily be felt in the glaciers themselves. In the short Galiano glacier, and perhaps in others where not observed, the response occurred before 1905, and in 1906 the four glaciers mentioned were

SHOUP GLACIER, PRINCE WILLIAM SOUND

A glacier front of only moderate height, but one beside which the man's figure (left of lower center) looks puny. The American soldiers stationed at Fort Liscum obtain their ice supply from this glacier cliff (see page 9).

exhibiting the full effects of the response in the sudden addition to their snow supply. As the abrupt melting of snow in the headwaters of a river causes a flood which, in time, sweeps to the very river mouth, so in these glaciers the great and unusual addition of snow and ice during the earthquakes has given rise to an ice-flood which has swept down to the glacier ends. On this theory, therefore, the phenomena observed are explained as the result of a glacier flood started by earthquake impulse.

The observations of 1905 and 1906 were sufficiently extensive to at least lend strong probability to this theory, and it has been quite generally accepted. It was, however, of great importance to apply further test to the theory and to study the later phases of the phenomena attending such glacier advance; and therefore it was with keen interest that the authors again turned their attention to the Yakutat Bay region in 1909 under the auspices of the National Geographic Society.

If the earthquake theory were the correct explanation of the remarkable changes observed in 1906, three things were to be expected: In the first place, other glaciers should by that time begin to show the effects of the glacier flood; secondly, those glaciers which had already been under the influence of the glacier flood should begin to show signs of its diminution, though just what these signs would be or how rapidly the glacier flood would subside could not be predicted; thirdly, no such profound, spasmodic changes in the glaciers should be found in regions on either side of Yakutat Bay outside the area of severe earthquake shaking.

A study of these three points was the foremost object of the expedition of 1909, and the results of this study were in all cases in support of the theory previously proposed. If further demonstration of the accuracy of this theory were demanded than that previously presented, the results of the expedition of 1909 supply enough to establish the theory on a firm foundation. This additional evidence will be considered under the three phases mentioned above, beginning with a consideration of the new advance.

ADVANCE OF GLACIERS BETWEEN 1906 AND 1909

Several of the glaciers of Yakutat Bay have as yet suffered no change as a result of the earthquake shaking, so far as can be seen. This is true, for instance, of the Fourth glacier, which lies just east of the head of Yakutat Bay; of the tidal Nunatak glacier, that has continued the recession which has been in apparently uninterrupted progress since 1891, and whose ice cliff is now a mile and a half or more farther back than in 1899; of the tidal Turner glacier, which appears to be almost as it was in 1890, 1899, 1905, and 1906; of the Hayden glacier, the easternmost tributary to Malaspina glacier, which is in the same state as in 1905 and 1906; and of several smaller glaciers which are in the same state as in 1905 and 1906. But three large glaciers have come under the influence of the glacier flood since last seen in 1906.

Of these the largest and least effected is the tidal Hubbard glacier, which seemed, in 1909, to have just begun to come under the influence of the glacier flood. This is an active glacier, and since first observed by Russell, in 1890, has been crevassed from side to side and has poured a steady stream of icebergs into the fiord from its 5 miles of ice cliff. But beyond the mountains the extreme eastern margin, blanketed by a cover of lateral moraine, has been in a semi-stagnant state, and, where it projected into the sea, rose as a dirt-stained ice cliff from which the discharge of icebergs was infrequent. Back from this ice cliff, on the land, was a moraine-covered ice slope in which little ice showed, and up which it was easy to climb to the glacier surface (see pages 16 and 35).

HUBBARD GLACIER IS EVIDENTLY ON EVE OF GREAT MOVEMENT

In 1909, however, this moraine-covered land slope of the glacier margin was being destroyed; the ice was pushing out

BRAIDED STEAM COURSES WHICH EXPLORERS FIND DIFFICULT TO CROSS

TRAVEL TO THE GLACIERS BY BOAT AMONG THE ICEBERGS AND OVER THE GLACIER SURFACES ON FOOT

THE AUTOMOBILE IN FRONT OF VALDEZ GLACIER (SEE PAGE 9)

through the moraine, and bare, steep, ice cliffs were developed in place of the former morainic slopes. The ice cliff was broken, and blocks of ice, dislodged, were falling to its base, while the moraine, in the grasp of running water liberated from the newly exposed ice, was being deposited on the mud flat at the base of the glacier, burying willow bushes and annual plants that had previously been growing there. From the sea cliff many icebergs were being discharged, proving still further that this margin of the glacier had begun to advance; but we could not be certain that the main part of the glacier was also moving forward more rapidly than before, although it seemed to us that the cliff was higher and there was more ice in the fiord, and more frequent discharge of icebergs than in 1905 and 1906.

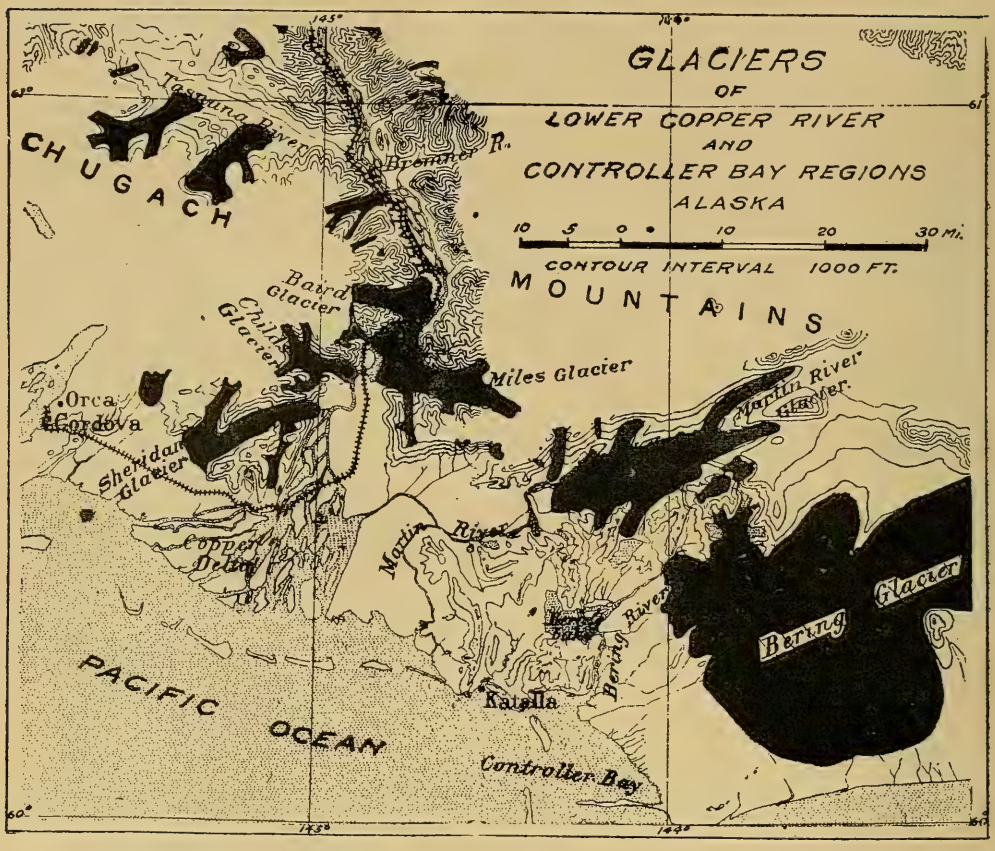
From the condition of Hubbard glacier we conclude that an advance under the flood impulse had just begun in the summer of 1909, certainly along the eastern margin, and perhaps throughout the entire glacier. It would, therefore, be of great interest to return to it in 1910 to see exactly what change follows, for in this case we seem to have discovered a glacier showing the very first signs of advance. It will also be interesting to observe whether all or only a part of the glacier feels the flood impulse, for Hubbard glacier is made by the union of two very large tributaries, and each of these has large feeders. By the flood explanation it is not to be expected that glaciers of different lengths, with different numbers of tributaries, and with different conditions in their reservoirs, will advance at the same time.

It is quite possible that the eastern side of Hubbard glacier will respond to the glacier flood at a different time and in a different amount than the western margin, which is supplied from an entirely different source. Indeed, even the same side may advance under the influence of the flood from some of its larger feeders, then halt, and later advance again under the flood impulse supplied from more re-

MILES GLACIER AND LAKE (SEE PAGE 13)

FERRY SLIP: STAGNANT PORTION OF MILES GLACIER ON LEFT

M. J. HENEY'S CONSTRUCTION CAMP 55, WITH TENT HOUSES



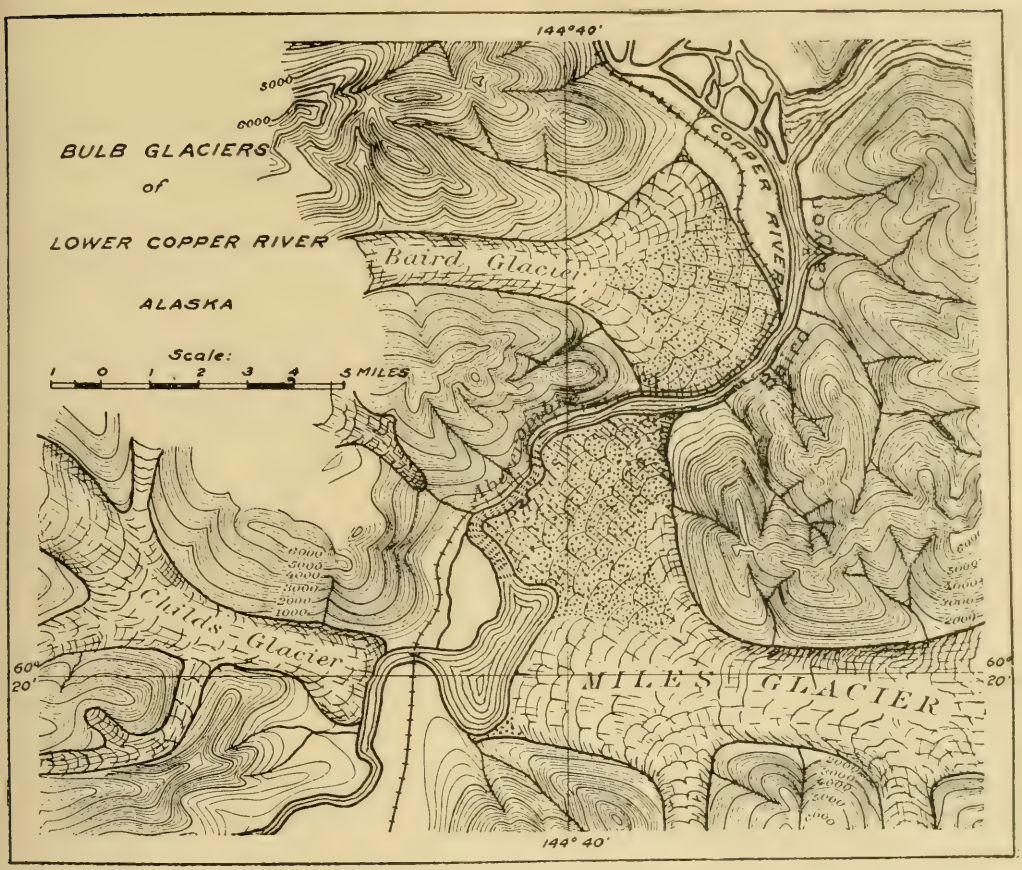
MAP OF PART OF ALASKAN COAST (AFTER U. S. GEOLOGICAL SURVEY)

Showing glaciers of lower Copper River. The water at the delta is so shallow that the terminus is at Cordova to the west. There are valuable coal fields between Bering and Martin River glaciers and rich copper deposits north of the Chugach Mountains (see pages 13 and 37).

mote reservoirs. The entire phenomenon of advancing glaciers as a result of earthquake shaking is so little known that it is difficult to accurately predict results, and consequently it is highly important to maintain observations so that this novel and interesting phenomenon may be more thoroughly understood.

LUCIA GLACIER HAD BECOME IMPASSABLE

The second glacier that has been brought under the flood impulse since last seen in 1906 is the Lucia glacier, which lies next west the Atrevida, and whose lower, stagnant end coalesces with the Atrevida glacier. The expedition of 1906 crossed the Lucia glacier from west to east in order to study the western margin of the Atrevida glacier, which had become so crevassed between 1905 and 1906 that it could no longer be crossed. The Lucia was then in the same condition as when crossed by the junior author in 1905 and by Professor Russell in 1890—that is, the Lucia glacier, fed by many tributaries, emerged from its mountain valley as a partly moraine-covered glacier, with so little crevassing that it could be easily traversed in any direction. Beyond the mountains it expanded into a piedmont bulb covered with moraine, and its outer margin was so stagnant that it was covered by a dense growth of alder and cottonwood. On the western side, near



THE COPPER RIVER AND NORTHWESTERN RAILWAY PASSING BETWEEN CHILDS AND MILES GLACIERS AND OVER THE STAGNANT ICE OF BAIRD GLACIER

Trains now cross the Miles Glacier Lake on a car ferry, pending completion of the bridge across Copper River. (Map after U. S. Geological Survey.) (See pages 13 and 37.)

Floral Pass, the glacier split against a rock hill, or semi-nunatak, sending a small tongue part way down the valley on the western side of the nunatak.

In 1909 the Lucia glacier was absolutely transformed. It was crevassed from side to side, so that the route to Floral Pass, so easily followed in 1890, 1905, and 1906, was no longer passable. The glacier was broken by great rents, enclosing table-topped areas of unbroken ice, on which the ablation moraine still stood, and along the margin, as well as within the mountain valley, was a maze of crevasses, seracs, and pinnacles, giving the ice surface the appearance of an ice fall, where but three years earlier one could walk in any direction with only an occasional crevasse to impede the journey. Along the eastern margin the breaking of the glacier was still in progress and the cracking of the ice and the falling of ice blocks was heard every few moments, while the moraine was all the time sliding down the ice face or into crevasses (p. 41).

Where in 1906 was a moderately sloping embankment of moraine-covered ice, up which we could easily climb at any point, there was in 1909 an ice precipice with jagged, serrated skyline, due to the recent breaking of the glacier. On the western margin, which we were unable to

visit, but saw from a distance, the ice had crowded up on the stoss side of the nunatak nearly to its top, while the distributary west of the nunatak had protruded entirely through its valley and was nearly, if not quite, united with the main glacier below the nunatak.

In the central part of the glacier the new-formed rents extended down into the previously nearly stagnant bulb, but not into the alder-covered zone. There the advance of the Lucia had not extended so far as that of the Atrevida in 1906, when the broken ice affected even a part of the alder zone of its piedmont bulb. But it seems probable that the advance of Lucia glacier, which was certainly in progress in the summer of 1909, was not as far advanced as that of the Atrevida in 1906. As will be seen from the descriptions which follow, the flood impulse is rapid and soon dies out. Quite probably the flood of the Lucia will have attained its height by 1910.

REMARKABLE TRANSFORMATION OF HIDDEN GLACIER

While the Hubbard glacier is apparently in a very early stage of advance, and Lucia glacier has not yet reached the maximum of its flood stage, the Hidden glacier has entered upon and completely passed through flood condition in the interval between 1906 and 1909. In late June, 1906, the Hidden glacier was seen and photographed from near the sea, but it was then so like its condition in 1905 that it was not studied further; but in 1905, because of certain interesting phenomena, it was studied carefully, and photographed from various points. It was then, and in 1906 still was, a low grade, smooth-surfaced glacier, almost, if not quite, stagnant, ending in a gently-sloping front, quite free from débris, over which one could easily travel in all directions. The ice front lay about 2 miles from the sea, and in the interval between Gilbert and Gannett's visit in 1899 and ours in 1905 it had receded about a quarter of a mile. Beyond the apparent front of the glacier, between it and the sea, lay a pitted gravel plain, partly resting on stagnant ice still connected with the glacier. Altogether the Hidden glacier was so perfect a type of an inactive valley glacier in a waning state that one would never have thought of predicting for it a sudden change to activity and complete transformation to a broken condition. Yet that is exactly what happened immediately after it was last seen in 1906, and possibly even late in that year (see pages 42–43).

Notwithstanding the almost magical transformation of glaciers to which we had by that time become accustomed, our astonishment was so great as almost to make us disbelieve our own senses when Hidden glacier burst upon our view in July, 1909. Russell called this Hidden glacier because, as he sailed up Russell Fiord, it was almost hidden from view, appearing for only a short time as its valley opened, revealing the glacier nestled between the steep mountain walls over 2 miles from the sea. As we rounded the northern wall of the valley in July, 1909, the glacier burst upon our view so high and so near that we at first thought it tidal. As a matter of fact, its front was still a quarter of a mile from the sea, but it was nearly 2 miles farther down its valley than in 1905 and 1906, and higher and steeper than the front then was. It had advanced over all of our bench-marks and important photographic sites which we had located primarily for the purpose of recording future recession. The most important of our sites was beneath 500 feet of ice and in front of it stretched 2 miles of glacier.

Not only had the glacier advanced, but it had become profoundly crevassed. However, the advance had occurred so long ago that ablation had healed much of the crevassing, making it possible for us to travel over parts of the glacier surface, though only when the party was roped together, and then by the use of much care, and with many detours around yawning crevasses. The glacier surface was far different from the smooth state of 1905 and 1906. It was a tumultuous series of great swells and troughs, with abundant crevasses, in spite of the pronounced

A SHARP CURVE IN THE RAILWAY AT ABERCROMBIE RAPIDS: A NARROW SHELF BLASTED OUT FOR THE ROAD

THE COPPER RIVER AND NORTHWESTERN RAILWAY UNDER CONSTRUCTION ON THE STAGNANT ICE OF BAIRD GLACIER (SEE PAGES 13-14)

Copper River on one side, ice beneath, glacial ice with moraine and forest on the other side

THE RAILWAY AUTOMOBILE AND MR WILLIAMS, ASSISTANT ENGINEER OF THE RAILWAY

Forest-covered Baird glacier in the background. The leaders of the National Geographic Society's Expedition traveled 125 miles in the car, through the courtesy of the Katalla Company, who are building the railway, and Messrs Hawkins and Williams.

ablation which had evidently been in progress since the glacier spasmodically rushed forward. So much ablation had taken place that we are certain that the advance occurred at least as early as 1907 and perhaps in 1906. The advance must have been rapid, occupying only a small period of time, for, at most, there were only three years for the advance, breaking, and partial healing by ablation, to a state permitting travel over the surface. It is a pity that there was no one at hand to witness the beginning and progress of this marvelous change in glacier condition, the most spectacular of all so far recorded in the Yakutat Bay region, or, for that matter, in all the world.

PRESENT CONDITION OF THE GLACIERS THAT ADVANCED IN 1906

Our second principal line of inquiry was with reference to the condition of the four glaciers whose remarkable advance was discovered in 1906. In the summer of that year the Variegated, Haenke, Atrevida, and Marvine glaciers were in a state of activity which contrasted strikingly with their inactive condition nine months before. The observations of 1906 were upon glaciers in full flood stage, and if, as proposed by the theory, this spasmodic transportation was the result of an impulse due to the accession of large quantities of snow and ice shaken down into the reservoir in a period of three weeks of earthquake shaking, it was to be expected that the full force of the advance would soon be spent.

It was, therefore, with great interest that we returned to an examination of the transformed glaciers. Our expectations were more than realized, for we were quite as unprepared for so sudden a cessation of activity as we had been for the spasmodic advance and breaking observed in 1906. From our study in 1909 it has become evident that the advance of the glaciers, begun between September, 1905, and June, 1906, ended before the summer of 1907. By this it is not meant to assert

that *all* forward motion ceased thus abruptly, though this also may have been true, but merely that the rapid movement which broke the surface of the glaciers into impassable condition came to an end at least as early as the beginning of the summer of 1907, and that the spasmodic advance, from beginning to end, was accomplished within a period of not over one year.

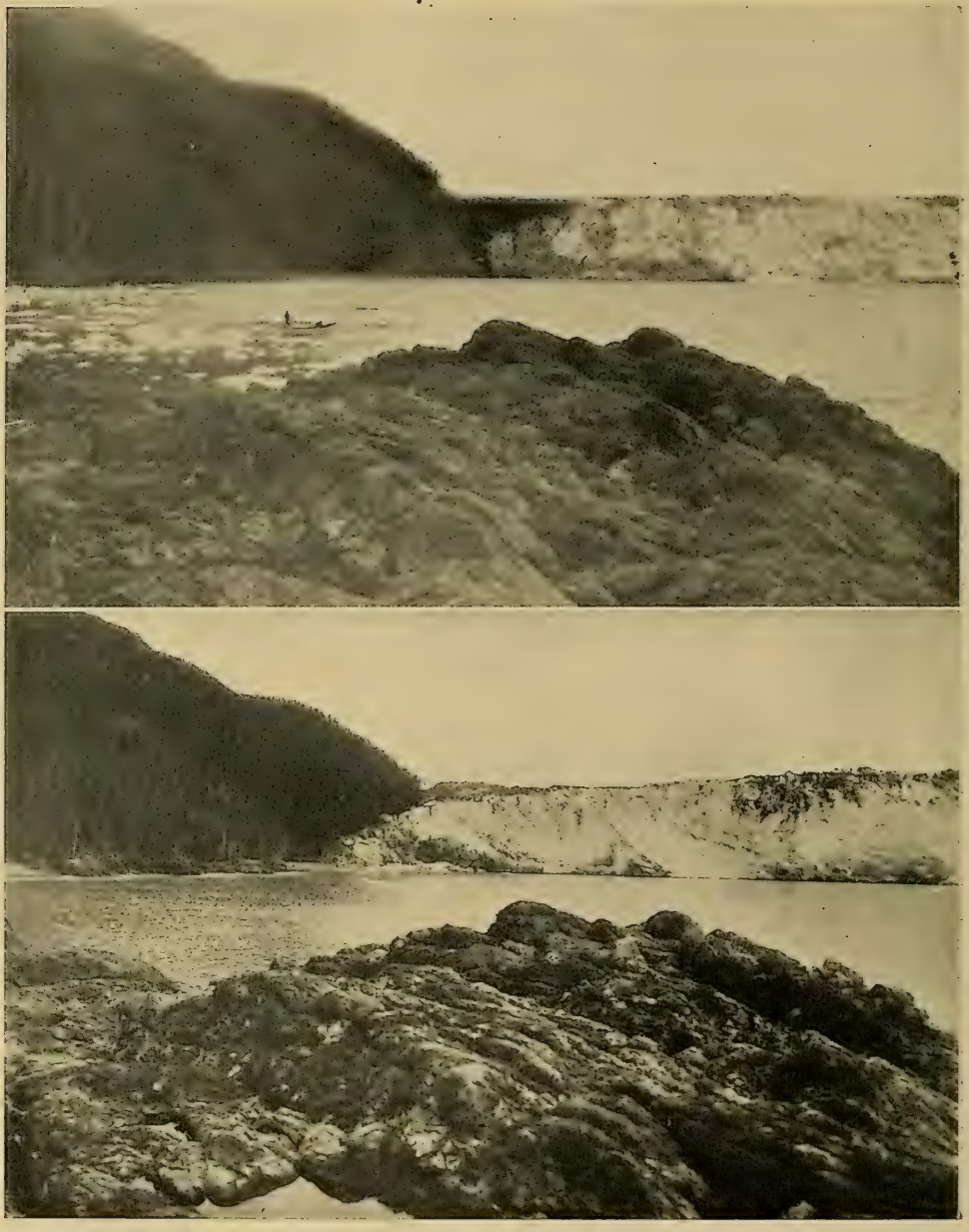
The evidence of this almost incredibly rapid change from stagnation to great activity, and then back again to stagnation, is clear and convincing, though in an article of this length it cannot be discussed with sufficient fullness to marshal all the proof. The proofs of the abrupt advance have already been stated in this paper, as well as much more fully in other publications relating to the studies of earlier years. That the advance so actively in progress in the summer of 1906 did not extend into the summer of 1907, is suggested by the extent to which ablation has healed the crevassing caused by the spasmodic advance. The ice surfaces upon which we could not travel at all in 1906 were again passable in 1909.

We walked across the lower end of the Variegated glacier, and crossed the Atrevida glacier to Terrace Point, and although we did not go to them, it was evident that both the Haenke glacier and the eastern, or Marvine, lobe of the Malaspina glacier could be traversed without great difficulty. For ablation to so heal the broken ice surface as to permit travel over it time is required, and it is inconceivable that the single season of 1907 was sufficient for this extensive ablation. In the period of time required must certainly be included the summer of 1907. Contributory evidence is supplied by Hidden glacier, whose entire advance and ablation to passable condition took place after June, 1906; but travel over this glacier is more difficult than over those glaciers which advanced early in 1906, for there has been less time available for the reduction of the roughened surface by ablation.

Other more definite proof that the advance ceased within a few months after our study of 1906 is furnished by each of the glaciers. The front of the advancing portion of Variegated glacier has gone no farther than where it stood when last seen in 1906; Haenke glacier front is not quite so far out now as then; the eastern margin of Atrevida glacier advanced a little further, but the extent of breaking out in the alder-covered stagnant bulb is the same as in 1906, even the same rings of broken ice in the alder thicket being present; and along the eastern margin of Malaspina glacier the forest growth on the ablation moraine of the stagnant ice was not entirely destroyed, although in the summer of 1906 it was disappearing at a rapid rate.

In a word, although the change in glacier condition between September, 1905, and June, 1906, was marvelous in these four glaciers, the changes between August, 1906, and July, 1909, have been of almost no consequence, excepting only such extensive ablation as to render the glaciers once more passable. It is not to be inferred, however, that ablation has so reduced the irregularities caused by the breaking of the glaciers in their flood stage as to bring about again the undulating, easily traversible surfaces of 1905. The condition of the glacier surfaces is far different from that of the period before the advance, and travel over them is as yet by no means easy. The surface rises and falls in a series of great waves and troughs, and crevasses are encountered at frequent intervals. Nevertheless, the ice surface of these glaciers more closely resembles the condition of 1905 than that of 1906. It is evident that they have once more relapsed into the stagnant or semi-stagnant state by which they have been characterized since first discovered and studied.

The observations of 1906 proved that the advance of the glaciers under the impulse of increased supply furnished by earthquake shaking was rapid, and the observations of 1909 prove that the impulse is spasmodic and of brief duration. The entire cycle, from gently undulating ice surface, through the broken stage of the glacier flood, and back to the normal

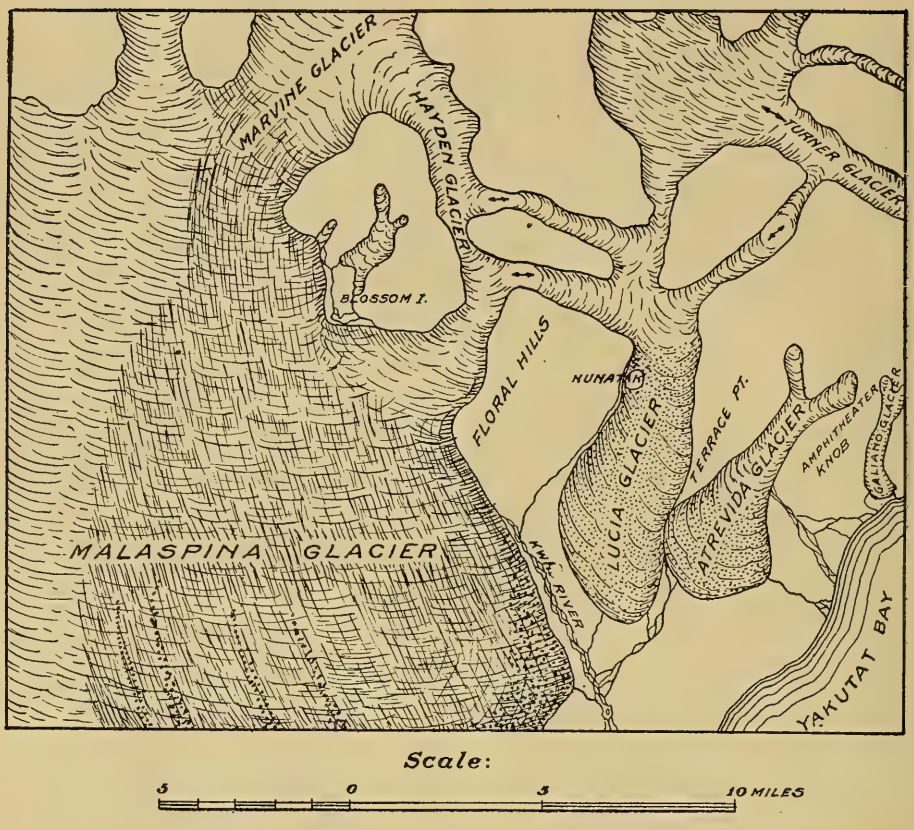


WEST MARGIN OF COLUMBIA GLACIER, AS PHOTOGRAPHED BY GILBERT IN 1899, AND BY THE NATIONAL GEOGRAPHIC SOCIETY'S EXPEDITION IN 1909, AFTER THE RECENT ADVANCE (SEE PAGE 37)

EAST SIDE OF COLUMBIA GLACIER, PHOTOGRAPHED IN 1909 FROM EXACT SITE UTILIZED BY GILBERT TEN YEARS BEFORE: ADVANCE SHOWN IN LOWER PHOTOGRAPH

COLUMBIA GLACIER ADVANCING INTO FOREST, OVERTURNING TREES AND SHOVING UP A MORAINE (SEE PAGES 9–13, AND 37)

ICE OF COLUMBIA GLACIER OVERTURNING MATURE FOREST



ATREVIDA, LUCIA, AND MARVINE LOBE OF MALASPINA GLACIER

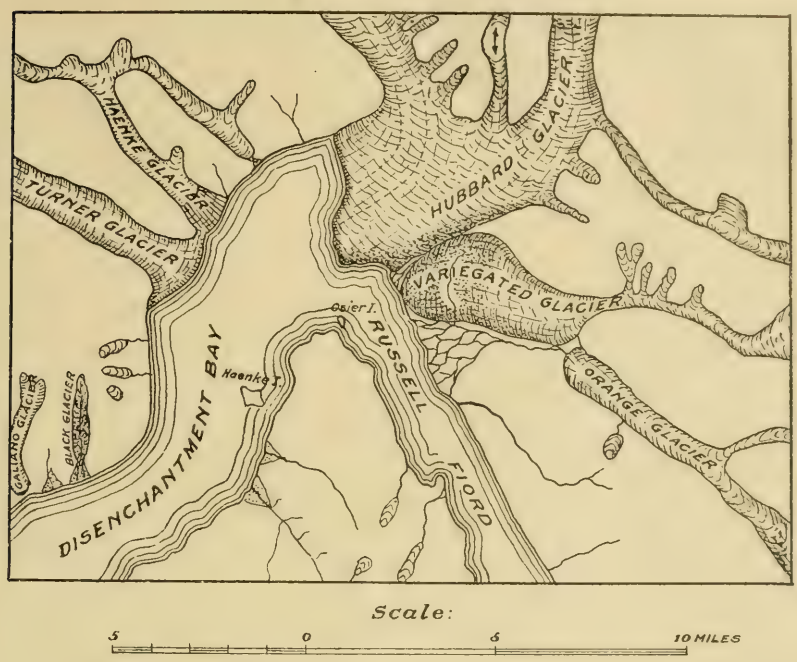
Atrevida and Malaspina glaciers advanced between 1905 and 1906, while Lucia glacier was advancing in 1909 (see pages 17, 24 and 25)

condition of the stagnant glacier, is compassed in a period of but a few years, say from four to six years. Surely the term glacier flood is warranted for such a sudden change in ice condition.

This is not the place for a discussion of the validity of the earthquake theory for these remarkable changes, but it may, nevertheless, be pointed out here that, while this theory accounts for all the facts, and stands all the tests applied to it, no other explanation that has so far been suggested can be considered even rational enough to be retained as an alternate hypothesis. We believe, therefore, that we are warranted in claiming that a new cause for glacier advance has been discovered, for the theory of advance under earthquake impulse, first put forward by the senior author as a result of his observations of 1906, has, by the additional evidence discovered in 1909, been put to such tests as to completely verify it.

GLACIERS OF OTHER SECTIONS SHOW NO EVIDENCE OF SPASMODIC ADVANCE DUE TO 1899 EARTHQUAKES

There is, however, one further test that we were able to apply as a result of the field work of the 1909 expedition. It has seemed to us reasonable to expect that, since the earthquakes of September, 1899, were centered in and about the Yakutat Bay region, the spasmodic advance of glaciers should be confined to that region, or, at least, should not be



VARIEGATED AND HAENKE GLACIERS

Which were stagnant and easy to cross in 1905, crevassed and impassable in 1906, and stagnant and passable in 1909. Hubbard glacier, perhaps, began an advance in 1909 (see pages 16, 17, 19 and 22).

noticed far to one side of the area of vigorous shaking. Just what is to be expected near the periphery of the area of maximum shaking we are not in a position to predict, though it is to be expected that there, also, some response, probably less spectacular, should occur. In a single field season we could not, of course, cover an extensive area in personal field work, but we were able to do some work in the Prince William Sound region and in the Copper River Valley, and we made some observations on glaciers visible from the steamer and made inquiries regarding them.

So far as we could learn from our inquiries none of the glaciers of the Inside Passage have undergone any notable transformation since 1899, excepting that of recession as exemplified especially in the Muir glacier. The Brady glacier, near which our ship anchored for the night, has not changed notably since 1905, when we last saw it, and we could not detect any changes in the great glaciers which descend the western face of the Fairweather Range, although it should be stated that most of these were seen from such a distance that we could have detected only extensive changes. These glaciers, together with the Brady, Muir, and others in this vicinty, are within the area shaken during the September, 1899, earthquakes and may be expected to respond, to some extent at least, to the effects of this shaking.

The natives residing at Dry Bay, 60 miles southeast of Yakutat Bay, report that in the summer of 1909 there were remarkable and long-continued changes in the volume of the Alsek River, which may be related to the advancing and breaking of some of the glaciers whose ends lie up this valley. We may expect advance in these glaciers, for their sources lie in the snow fields of mountains within the area of vigorous shaking during the 1899 earthquakes.

THE HUBBARD GLACIER IN 1909 FROM OSIER ISLAND

Our actual field work on areas outside of the Yakutat Bay region was entirely to the northwest. Here, in Prince William Sound, we found the large Valdez glacier continuing the recession which has been in progress, with one possible slight advance, since 1899. There has also been a retreat since 1898 of the Shoup glacier, which, however, is smaller than the Valdez. On the other hand, the still larger Columbia glacier, the greatest in this region, and comparable to the Hubbard, was again advancing into the forest in 1909, as it had seven years before 1899, when studied by Dr Gilbert. Prof. U. S. Grant has shown that there was a period of recession in the Columbia glacier between 1899 and 1905, followed by slight advance between 1905 and 1908. The present advance, which has gone beyond that of 1892, does not appear to be of the same order as that of those Yakutat Bay glaciers which are advancing under the impulse of earthquake shaking. It may be the beginning of a spasmodic movement, or it may be a slow forward swing such as comes from moderate variation in snow supply. Moreover, we would hardly expect the largest glacier to be the first to advance under the earthquake influence. However, it will be important to watch this glacier in the next few years (pp. 30–33).

In the Copper River Valley, although several other glaciers were seen, and showed no sign of recent notable advance, we gave special attention to the three largest, the Baird, the Miles, and the Childs. That the Baird glacier has long been stagnant is proved by its moraine-covered piedmont bulb, bearing a growth of mature alder (see pages 24–25).

The Miles glacier is more active and discharges icebergs into the Copper River from a long ice cliff; but its alder-bearing, moraine-covered piedmont bulb on the north side shows a long period free from advance, photographs and maps by Abercrombie in 1884, Allen in 1885, Hayes in 1891, and Schrader in 1900 verifying this inactivity.

The Childs glacier, which is also actively discharging icebergs into the Copper River directly opposite the Miles, has not recently been much farther out than now, but it is reported by the engineers of the Katalla Company, who are building the Copper River Railway, to be more active in 1909 than previously, and to have advanced somewhat.

In view of the great economic importance of these three glaciers, between two of which, and *on* one, the Copper River Railway is now built, it is of high importance that these three glaciers be carefully mapped and studied. The fate of the railway to the copper fields depends upon the behavior of these three glaciers, and since they are now so easily accessible and so interesting—the only case in the world where two large iceberg-discharging glaciers can be seen from a railway train which passes between them—they are likely to be much visited in the immediate future.

From our observations and inquiries of 1909 we are led to believe that the spasmodic advance of glaciers, so vividly illustrated by six of the glaciers in the small area of Yakutat Bay, has probably not been duplicated in the regions to the northwest and southeast. It is, of course, recognized that such negative evidence is not wholly conclusive, since our observations have not included all the glaciers or even a large proportion of them. But it is, nevertheless, considered as contributory evidence that in our search to the northwest and southeast of the Yakutat Bay region we have so far failed to find a duplication of the marvelous transformation of glaciers observed there. So far as it goes, this evidence tends to verify the theory of local cause for glacier advance in Yakutat Bay. Further study in the areas beyond the limit of vigorous shaking by the 1899 earthquakes should be expected to bear similar testimony.

There have been world-shaking earthquakes originating near the Prince William Sound and Copper River regions, of which those of October 9, 1900, and February 14, 1908, are good examples, though less severe than the three weeks of earthquakes at Yakutat Bay in Sep-

MORAINE-VENEERED EAST MARGIN OF HUBBARD GLACIER IN 1909

Showing dark-colored ice projecting through moraine, as if glacier were about to advance

tember, 1899. Avalanches accompanied these shocks also. These facts may complicate the situation somewhat.

OTHER RESULTS OF THE NATIONAL GEOGRAPHIC SOCIETY'S 1909 EXPEDITION

The problems connected with the remarkable changes in the Yakutat Bay glaciers, and with the explanation of these changes, have claimed first attention from the authors, for these seemed to be the most inviting and important phases of work on Alaskan glaciers at present open to the student. It scarcely requires statement, however, that other problems also received attention of students of glaciers and glaciation whose good fortune it was to be given the opportunity to study in a field so rich in glacial phenomena as that of the Alaskan coast. This is not the place for a full statement of the results of our summer's work; that must be deferred until the appearance of our final report. Still a summary of some of the more important phases of these other results may appropriately be introduced here.

The Alaskan Coast region is not only the seat of the largest glaciers on the continent, and in fact of some of the largest in the world, outside of the Arctic and Antarctic regions, but also of some of the most interesting and least known. Therefore any study of these glaciers promises important results, and studies of one year will serve as a basis for future comparative studies. From this latter standpoint it has seemed to us highly important not only to provide descriptions of glaciers, but also to prepare maps of such detail as to give an accurate basis for future comparative study. Accordingly, the topograhper of the expedition, Mr W. B. Lewis, whom the U. S. Geological Survey detailed for this work, assisted by Mr E. F. Bean, has made a series of detailed contour maps of the principal glaciers studied. These will be published with our final report. Supplementary to maps, photographs from

THE ADVANCING MARGIN OF ATREVIDA GLACIER BROKEN BY RECENT FORWARD MOTION

In 1905 this was a moderately sloping, moraine-covered ice margin; in 1906 it was a jagged cliff from which blocks of ice and stones were constantly falling into the forest, which was being overwhelmed (see pages 17 and 29).

selected points, which can again be occupied, are of high importance. The expedition was fortunate in having the services of Mr O. D. von Engeln, a skilled photographer trained also in physiography, to the results of whose work we are much indebted; and his photographs taken during this expedition as well as those which he took on the expedition of 1906 will be of great value in all future work on these glaciers. To these three men the authors are especially indebted for careful, conscientious work in their fields, as well as for generous assistance whenever and wherever needed. All future students in these fields will profit from their excellent work.

The glaciers of the Alaskan coast are especially interesting to the student of continental glaciation because here large masses of ice descend into a cool, damp, temperate climate, much as was the case at the base of the Alps and other mountains during the Glacial period. The wasting margins of these glaciers furnish much information of value in the study and interpretation of the phenomena of continental glaciation in Europe and

NUNATAK GLACIER IN 1899 (PHOTOGRAPHED BY G. K. GILBERT)

NUNATAK GLACIER TEN YEARS LATER

Photograph by the National Geographic Society's Expedition from exactly same site, glacier having retreated out of sight (see pages 8 and 44)

LUCIA GLACIER IN 1909 FROM TERRACE POINT

It is crevassed and moving rapidly. In 1890, 1905, and 1906 it was stagnant and without crevasses. The nunatak in the background is being overridden (see pages 24–25)

VIEW OF HIDDEN GLACIER IN 1909, TAKEN FROM SAME POINT AS THE PICTURE SHOWN ON PAGE 43 (SEE PAGE 26)

HIDDEN GLACIER IN 1906

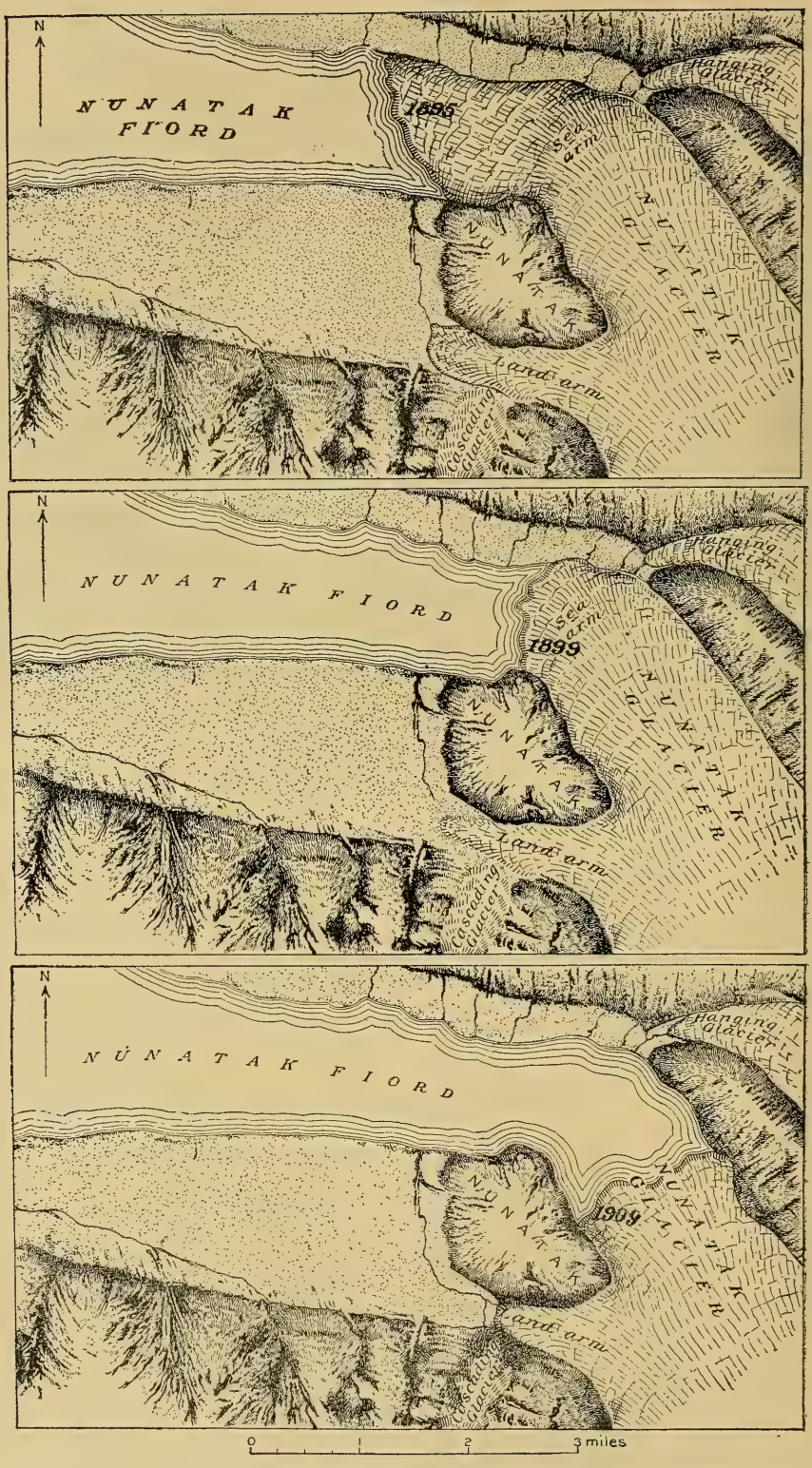
This photograph was taken from the same point as the view of Hidden glacier in 1909, given on page 42. The glacier has advanced nearly two miles in three years

America. In our expedition especial study was made of the piedmont ice bulbs into which so many of the glaciers expand on emergence from their mountain valleys; and in this connection the ablation moraines which accumulate on the wasting surfaces of the stagnant piedmont ice masses, and the deposits accumulating around their margins, were given particular attention. A statement of the results of these studies must for the present be postponed.

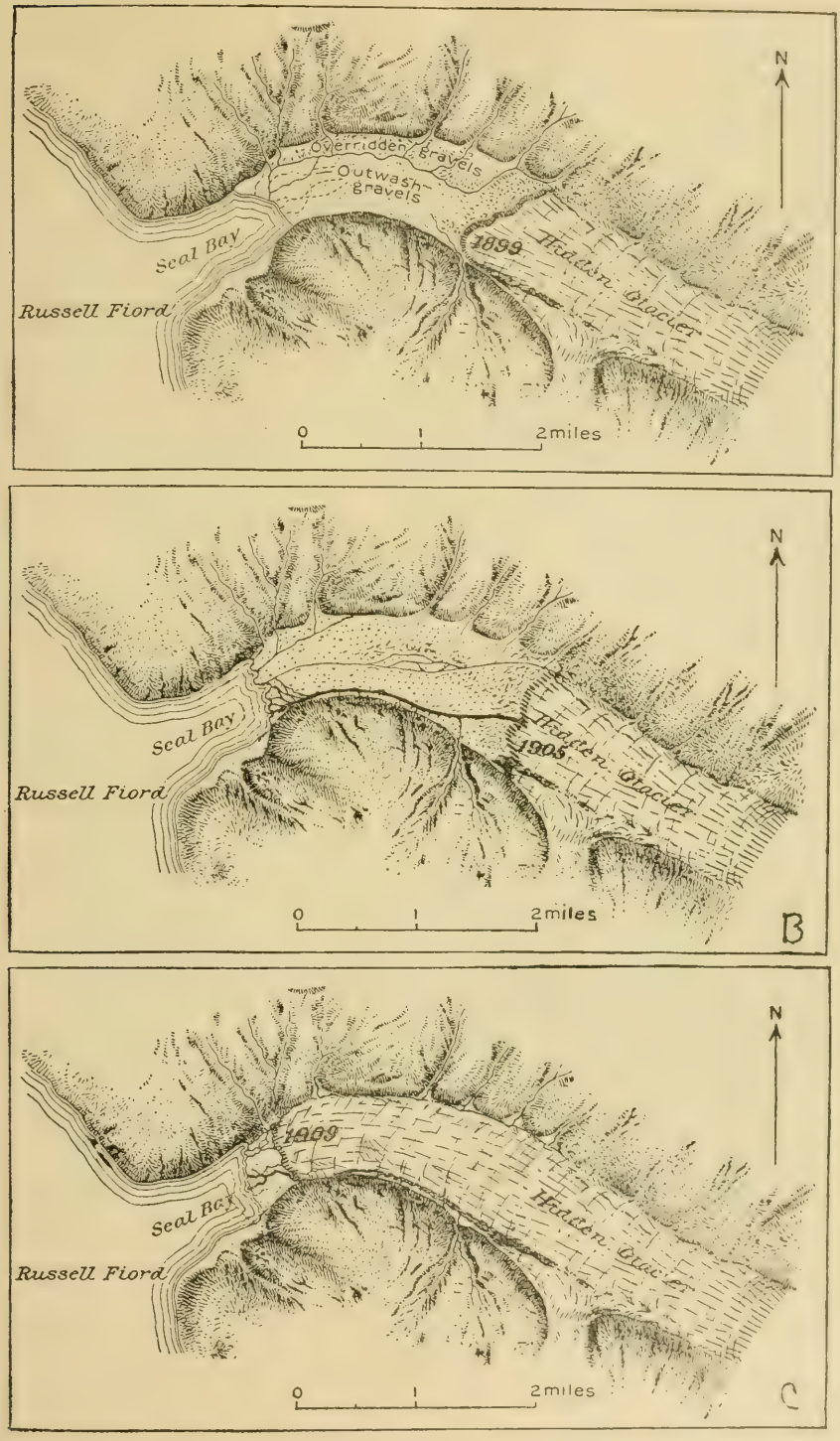
Another line of inquiry to which attention was given was the cause of glacier motion, upon which the advancing glaciers throw light. The sudden forward movement of a glacier, such as observed in Yakutat Bay, is difficult to explain on the basis of some of the current hypotheses for glacial motion. On the hypothesis of plastic or viscous flowage, on the other hand, the phenomena are all easily explained. A number of facts of observation in the summer of 1906 and 1909 tend toward the verification of this hypothesis. The discussion of this subject must also be left for our final report.

Other problems which will be discussed in the full report deal with questions relating to the former extension of the glaciers. During the period of maximum glaciation, ice filled the entire Yakutat Bay inlet and discharged icebergs into the Pacific; and at the same time the Copper River Valley was filled, and ice occupied the entire Prince William Sound, at least on the eastern side to which our studies were confined. The erosive work performed by these great glaciers has, in part, shaped the various inlets and valleys, while their deposits have left records of considerable scientific interest.

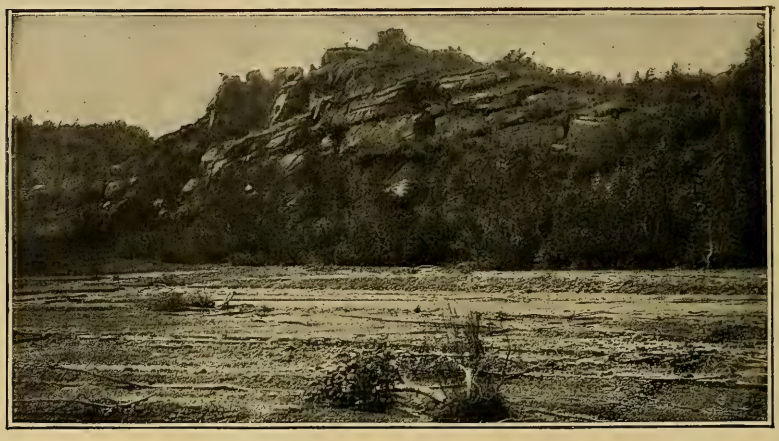
In view of the fact that only two parts of the coast have so far been studied, it will not, of course, be possible to enter into a comparative study of the phenomena of former glaciation of all



NUNATAK GLACIER IN 1895, 1899, AND 1909 (TOPOGRAPHY AFTER GANNETT)
This has had continuous steady retreat, but may yet advance under the earthquake-avalanche impulse (see page 40)

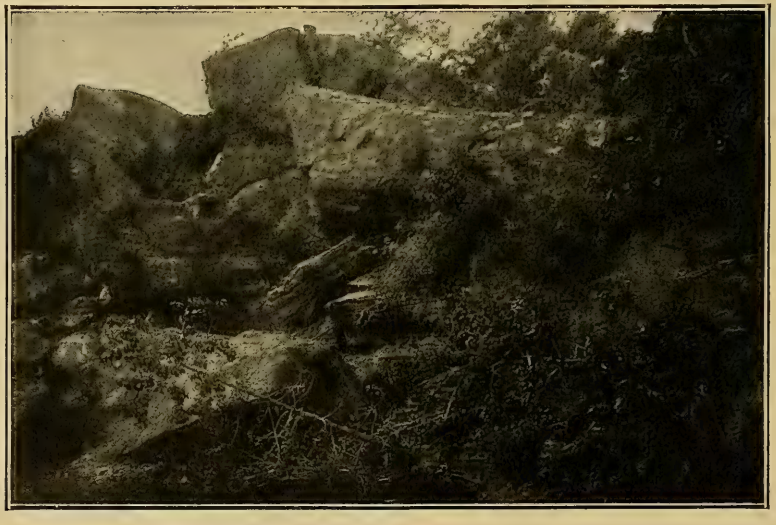


HIDDEN GLACIER IN 1899, 1905, 1906, AND 1909 (TOPOGRAPHY AFTER GANNETT) (SEE PAGES 26, 42–43)



BROKEN EASTERN MARGIN OF THE MARVINE LOBE OF MALASPINA GLACIER, FROM ALLUVIAL FAN OF KWIK RIVER (SEE PAGES 17 AND 28–29)

The broken ice cliff has protruded through the morainic soil and the forest. Blocks of ice fell from this cliff as the party passed, trees crashed down, and the morainic soil was constantly sliding down. Photograph taken August 11, 1906.



BLOCKS OF ICE PROTRUDING THROUGH MORAINIC SOIL AND FOREST COVER, EASTERN MARGIN OF MALASPINA GLACIER (SEE PAGES 17 AND 28–29)

Cottonwood trees, in full leaf, overthrown by the recent thrust that broke the glacier margin. Photograph taken August 11, 1906

THE SURFACE OF MARVINE GLACIER IN 1906, SHOWING THE DEEP CREVASSES WHICH MADE ITS CROSSING IMPOSSIBLE

The National Geographic Society's Expedition three years later, 1909, found these crevasses healed and the surface comparatively smooth and easy of traverse (see pp. 17 and 28-29)

Alaska; but enough has already been seen to make it possible to compare two widely separated regions, and to show that their glacial history has been different. While in both cases ice formerly extended beyond the present limits, the Prince William Sound and Copper River regions have not shared in an important episode of recent great ice advance, of which the evidence is so clear and convincing in Yakutat Bay and Glacier Bay. Why one part of the Alaskan coast should have been favorable to an advance of glaciers to a distance of many miles, and then to recession of these glaciers, while another part gives evidence of no such oscillation, is an interesting question. Other notable differences in glacier condition are also found, such, for example, as the difference between Columbia glacier, which is now farther out than it has been for at least a century and is still advancing, and the Valdez, Nunatak, Muir, and other glaciers, which are now greatly shrunken as compared with their condition a few years ago. Some of these problems cannot be adequately discussed until a wider area has been studied and a greater body of fact accumulated.

In conclusion, the authors wish to express their opinion that the problems of Alaskan glaciers and glaciation present a field for geographical research of the very highest scientific importance. In so large a field not all the glaciers, and in

GALIANO GLACIER (SEE PAGES 14 AND 59–62)

This picture represents in miniature all the conditions of the Malaspina glacier. The white snow fields in the background are constantly feeding the glacier, while in the foreground the ice has been so thickly covered with earth and rocks from the mountain sides that sturdy shrubs have grown up and make it difficult to believe that only a few feet beneath is the solid glacier ice.

MORAINE-COVERED FORESTED EASTERN MARGIN OF THE MARVINE LOBE OF MALASPINA GLACIER

The ice, recently thrust forward, has protruded through the soil; the trees are tilted at various angles and overturned; and the underlying ice, exposed to air and rain, is rapidly melting. Streams of water and of liquid mud descend the slope.

fact not all the larger glaciers, can be given careful study for years to come; for not only are there hundreds of such glaciers, many of which are still unnamed, but large numbers of them are so inaccessible that they can be studied only by special expeditions, expensive from the standpoint both as to time and of money.

While ultimately it is to be hoped and expected that all of these glaciers will be studied and mapped, the present needs can be met by a study of a few selected areas in which it is to be expected that the principal phenomena of Alaskan glaciation will be exhibited, and from which facts can be observed which will solve some of the larger problems and furnish basis for future study which will solve others.

In selecting these areas first consideration should be given to the scientific promise; second, to the variety of phenomena, and third, to the expenditure of time and money. From the latter standpoint accessibility is the key. Alaska is being rapidly opened up by road and railway building and river navigation, and what is today quite inaccessible, may in a few years be easy of access; therefore it seems hardly wise, in view of the broad field of opportunity, to expend large amounts of time and money in a study of what a few years hence may be reached with ease in far less time and at a far less expense.

ADVANCING ALTREVIDA GLACIER IN 1906 (SEE PAGES 17, 28–29, AND 39)

Showing the deep, impassable crevasses which are characteristic of a glacier during its advance

ALTREVIDA GLACIER IN 1909 FROM SAME SITE

Showing crevasses healed and surface covered with ablation moraine, an accumulation of earth and rocks from the mountain slopes (see pages 17, 28–29, and 39)

THE RESURRECTED FOREST: NEAR MUIR GLACIER

Photo from "Harriman Alaskan Expedition." Copyright, 1902, by E. H. Harriman

COLUMBIA GLACIER IN 1899

Photo from "Harriman Alaskan Expedition." Copyright, 1902, by E. H. Harriman (see also pages 30–33)

In view of the promise which this field of research holds forth, and of the considerations just stated, the authors have set themselves the task of outlining what seems to them a desirable program for the study of Alaskan glacial phenomena, so as to bring forth the results which seem to them most important, as follows: (1) Annually for several years a brief visit to Yakutat Bay, perhaps combined with a further study of Malaspina glacier if the advance of its tributaries permit travel over it, a study of the large glaciers of the Alsek valley, the Fairweather coast, etc.; (2) a more detailed study of the glaciers of Prince William Sound and the lower Copper River Valley; (3) the glaciers of the Inside Passage from the Canadian boundary to Cross Sound and the Muir Inlet; (4) the Controller Bay region, and the great piedmont Bering glacier; (5) the glaciers on the north side of the Saint Elias Range and in the Mount Wrangell region; (6) glaciers and glaciation in the great Alaska Range, the Endicott (Rocky) Mountains, the Alaska Peninsula, etc. If such work could be carried on consecutively, as part of a matured plan, the highest results for comparative purposes would be secured; it would be a notable contribution to science if the National Geographic Society should undertake an investigation of this scope.

PHOTOGRAPHY IN GLACIAL ALASKA

By O. D. von Engeln

Photographer of the National Geographic Society's Alaskan Expedition of 1909

ALMOST every subject of geographic interest has one or more phases of which photographic records can be made. It may therefore be inferred that a large number of the readers of the National Geographic Magazine are photographers, and that many of them are engaged in the fascinating task of carrying the camera into the remote places of the earth, as the pages of the Magazine itself testify.

The opportunity to focus a lens on scenes hitherto unpictured is compensation in itself, but an equal interest in such work lies in the difficulties which must inevitably be encountered and overcome when working with the camera away from the conventional dark-room, with its electric ruby-light and other conveniences. To "bring out" a collection of good negatives under such conditions becomes a worth-while task, and one which is in few places more difficult, probably, than in glacial Alaska, especially from that part of this region which is its focal point—the coast along the center of the great Gulf of Alaska.

It has been the privilege of the writer to do the photographic work of two expeditions to this region—that of the National Geographic Society's party of the past summer, and, in 1906, with a United States Geological Survey party. The following paragraphs have been written in the belief that the experiences recorded may be of interest and value to others who are engaged in similar work.

The photographer on a trip to Alaska will find subjects for his camera on the first morning after the sailing from Seattle in the personnel of the passengers. It must be understood that this does not apply so particularly to the excursion steamers, which carry tourists to the interesting points along the Inside Passage, but refers more especially to the boats which carry both passengers and freight to the mining towns and fishing stations scattered along the southeastern and southwestern Alaskan coast, with longer stops at the coast terminals of important routes to the interior mining fields. The second-class passengers on such a steamer are in the main typical